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Identification of suitable high density planting system genotypes its response to different levels of fertilizers compared with *Bt* cotton

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ABSTRACT : The experiments were conducted with objectives to find out suitable genotypes for high density planting system, assess the performance of genotypes under high level of nutrients and also to find out optimum level of nutrients as compared to existing system (RCH 2*Bt* with conventional spacing (90 x 60 cm) to achieve higher productivity and profitability in cotton at Central Institute for Cotton Research, Coimbatore in 2011-2012 and 2012-2013. The *hirsutum* earlymaturing compact with short sympodial genotypes *viz.,* Anjali, C1412, and CCH7245 were planted at high density (45 x 15 cm) and compared with RCH 2 *Bt* planted at conventional spacing (90 x 60 cm). The selected genotypes were combined with four levels (75,100,125 and 150% of RDF) of nutrients tried in sub plot of split plot design and replicated thrice. The conventionally planted RCH2 *Bt* had been recorded significantly the highest growth and yield attributes (no of bursted bolls (21.8), single plant seed cotton yield (96.4 g) and boll weight (4.7 g)).However, relative parameters, the significantly highest number of bolls per unit area (m^2) counted (number of bolls of 81.4 and 99.2 at 90 and 120 DAS, respectively) and seed cotton yield (2513 kg/ha) harvested with Anjali planted at 45 x 15 cm followed by CCH7245 and C1412. Higher/plant biometric and yield attributes observed with RCH 2 *Bt* had not reflected in seed cotton yield because of agronomical advantage associated with high density planting system (45 x15 cm), which had resulted in 252 to 843 kg/ha higher seed cotton yield than RCH 2 *Bt*.The significantly highest gross return (₹1, 04, 780/ha), net return (.60, 231/ha), benefit cost ratio (2.61), water use efficiency (64.4 kg ha-cm) and water productivity (26.8 /m^3) were observed with cultivation of Anjali under high density planting system. Higher nutrient uptake was observed with high density planted genotypes. Enhanced application of nutrient levels (75,100,125 and 150%) did not significantly influence growth and yield attributes, seed cotton yield, quality parameters and economic returns except soil available nutrients. The results summarized that high density planting of Anjali (45 x 15 cm) and application of 125 per cent of recommended nutrient level is more productive and profitable

Key words : *Bt* cotton, genotypes, nutrient levels, high density planting system

Cotton is the most important commercial crop of India which contributes around 65 per cent of the raw material to the textile industry and provides employment to 60 million people (Ajaykumar (2014)). Area and production wise, India ranks first (11.8 m ha) in global scenario about 34.0 per cent of world cotton areaand productionof 356.1 lakh bales. . Concomitant with the steep increase in adoption of *Bt* cotton hybrids, favorable Government policies and vigorous promotion of technological adoption in certain regions, its average productivity has increased from 302kg/ha in 2003 to 568kg/ha in 2016-2017 (AICCIP, 2017). However, the productivity reached plateau and the last five years productivity is not increasing whichranged from 503 to 552kg/ha. In cotton productivity front, we are far behind in comparison to Australia (2055 kg/ha), Brazil (1415 kg/ha), China (1403 kg/ha) and world average (759 kg/ha). In this context, it is pertinent to mention that an urgent need has arisen to enhance the productivity from present level to 1000 kg/ha under irrigated condition and 500-600 kg lint per hectare under rainfed condition (Kranthi, 2013). Cotton is capable of producing acceptable yields in a wide range of plant populations (Muhammad Iqbal *et al.,* 2012). This is fortunate from a historical perspective as cotton stand establishment observed in the country. However, the general conclusion may not be applicable to all germplasms / situations; high density planting with compact genotypes proved, as high potential system of cotton cultivation in many situations. Many cotton producing countries like Brazil, China, Australia, Spain Uzbekistan, Argentina andGreece tested, proved and adopted narrow row planting system of cotton as tool to achieve higher productivity (Rossi *et al.,* 2004). Increased plant density would be beneficial to cotton yield in the lower fertility field(Dong *et al.,*2010).High density planting system has been suggested as an alternative strategy instead of conventional one to increase yield as reported by Jahedi *et al.*,(2013

In other side, cotton is labour intensive crop, ever increasing labour scarcity, cost of labour and decreasing labour efficiency resulted into higher cost of cultivation thus erode the profitability of cotton farming. Prevailing manual picking cost constitute about 30-40 per cent of total cost of cultivation;, which necessitate machine picking, thus ultimately warrant high density planting system with compact genotypes for its suitability. With the available current technology, cotton could be sown more closely to make high density system. The system had not been given importance in earlier years might be due to enhanced pest load. Our improved capabilities and knowledge base on pest management, it is possible to contain pest menace. Keeping the above facts in view the experiment was made with objective to find out suitable genotype for high density planting system, assess the performance of genotypes under high level of nutrients and also to find out optimum level of nutrients as compared to existing system (RCH 2 *Bt* with conventional spacing) to achieve higher productivity and profitability in cotton.

MATERIALS AND METHODS

Studies were conducted during growing seasons 2011-2012 and 2012-2013 at Central Institute for Cotton Research, Coimbatore(N 11° ,E 77° with an altitude of 427.6 m above MSL) Tamil Nadu,India.The area has a subtropical climate with annual rainfall of 620 mm. The soil type is clay loam, low in available N , medium in available P and high in available K with a pH 8.4 and EC 0.3 dS/m. Soil test on micronutrient showed 0.41, 1.0, 3.14, 2.41 and 0.06 ppm of DTPA extractable zinc, copper, manganese, iron and boron (hot water extract) respectively. The crop received rainfall of 744.5 and 697.0 mm respectively during the year of 2011-2012 and 2012-2013 .The site is a double cropped irrigated upland with cotton cultivated during August to

March. The *hirsutum* non *Bt* early maturing compact with short sympodial genotypes *viz.,* Anjali, C1412, and CCH7245 were planted at high density (45 x 15 cm) and compared with RCH 2 *Bt* was planted at conventional spacing (90 x 60 cm). Planting took place on 16/8/2011 and 5/9/2012, and seedlings at 15 DAS (Day after planting) were thinned out in order to obtain the following final plant population densities: a) 1,48,148 plants/ ha in high density ; b) 18,518 plants/ha in conventional spacing. The selected genotypes were combined with four levels (75,100,125 and 150%) of nutrients tried in sub plot of split plot design and replicated thrice. The straight varieties were selected for HDPS; hence recommended level of nutrients forstraight varieties, 60:30:30 kg/ha of N,P_2O_5 and K_2O/ha was followed for high density genotypes. The existing hybrid recommendation of 90:45:45 kg/ ha of N, P_2O_5 and K_2O/ha was adopted for RCH 2 *Bt*. In both years, the cotton was grown under irrigated condition and water was applied through ridges and furrows methods from August to January. (3 irrigations, 50 mm in each irrigation).Weed control practices included pre-plant incorporated pendimethalin 1.25 kg ai/ha (stomp extra) and hand hoeing to maintain weed-free plots. The harvesting (29.2 m^2) took place by hand to measure seed cotton production. Randomly selected plants (ten) were used for biometric observations from each replication to also determine fiber quality parameters. Laboratory gin machine was used to separate the fiber and seed. Light interception was measured by line quantum sensor.Weed dry matter production and weed smothering efficiency were worked out at 30 and 60 DAS. Fibre quality parameters were estimated by using HVI (Statex-Fibrotex). Fibre quality index (FQI= LT/”M, where L, 2.5% span length (mm), T, fibre bundle tenacity at 3.2 mm micron (g/tex) and M, micronaire value), count (C=0.196 FQI –16) and count strength product (CSP=1.740 FQI + 1600) were also worked out. The apparent water use productivity (AWUP) calculated using the following formula as used by Gangwar*et al.*, (2005). AWUP = (Equivalent yield of a system/ ha)/ (Total quantity of water used in ha of land in cm).Economic Nutrient Use Efficiency (ENUE) is calculated in terms of economic produce grain or seed yield/rupee invested/ha on nutrient fertilizer. It is expressed in kg/, ENUE= (Grain or seed yield (kg /ha)) / (Amount invested on nutrient fertilizer (/ha)). Relative production efficiency (RPE) was calculated using the following formulae as under: RPE = (EYD-EYE)*100/EYE, Where EYD is the equivalent yield under improved/diversified system, while EYE is the existing system yield (Sankaranaryanan *et al.*, 2012). Relative Economic Efficiency (REE) is a comparative measure of economic gains over the existing system. It is expressed in percentage (REE = (DNR-ENR)*100 ENR^{-1}), where DNR is the net return obtained under improved/diversified system, while ENR is net return in the existing system. Prevailing market price of different agro inputs, price of *kapas* as per the market value of relevant count were considered while calculating comparative economics. Statistical analysis on pooled data was performed for all results. All data were subjected to analysis of variance at $P< 0.05$. To estimate the significance between means we used standard error of difference and critical difference.

RESULTS AND DISCUSSION

Growth characters : The genotypes (V1,Anjali, V2,C1412, and V3,CCH7245) planted under high density planting system (45 x 15 cm) with population of 1,48,000/ha were compared with conventionally planted (90x60cm) *Bt* cotton hybrid, RCH2 *Bt* (18,518 plant/ha) with nutrient levels (75,100,125 and 150 per cent) .The results revealed that plant height, sympodia, nodes did not vary significantly at 45 DAS amongst genotypes. The conventionally planted RCH2 *Bt* had been recorded significantly the highest sympodia of 6.2 at 45 DAS, 16.8 at 90 DAS, and 19.4 at 120 DAS; monopodia 1.5 at 45 DAS, 2.3 at 90 DAS and 2.4 at 120 DAS; plant height of 80.6 cm at 90 DAS, 83.4 cm at 120 DAS; bolls/ plant of 20.2 at 90 DAS and 29.3 at 120 DAS. RCH 2 *Bt* planted at conventional spacing (90 x 60 cm) might have avoided inter plant competition and produced higher growth characters. A cotton plant will sense the proximity of its neighbors and respond by modifying its growth habit(Chenshuyan *et al.,* 2010).From the plant's perspective, maximum growth is achieved if competition is kept to a minimum (Guthrie *et al.*, 1993). Genetic factor in addition to inter plant competition imposed by planting under high density may be the reason for less growth characters associated with ,Anjali, C1412, and ,CCH7245.*Intra* plant competition is compounded by higher plant densities (>60,000 plants/ acre), drastic growth modifications result is observed (Yao *et al.,* 2017).However, bolls/unit area counted found that the significantly highest boll/unit area (m^2) with Anjali planted at 45 x 15 cm(no of bolls of 81.4 and 99.2/ m^2 at 90 and 120 DAS respectively) followed by CCH7245 and C1412. The result on relative growth parameters includes LAI and dry matter production (DMP) exposed that the significantly highest LAI of 0.6 at 45 DAS, 4.0 at 90 DAS and 3.1 at 120 DAS and dry matter production of 3605 kg/ha at 90 DAS and 5231

Table 1. Growth characters of genotypes as influenced by nutrient levels under high density planting system at 45 DAS (pooled data)

Genotypes	Plant height(cm)	Sym-podia	Mono-podia	Squares	LAI	Nodes	DMP (kg/ha)
V1-Anjali (148148/ha)	25.2	5.2	0.2	5.8	0.5	10.1	1708
V2-C1412 (148148/ha)	23.0	4.3	0.2	5.2	0.5	9.4	1624
V3-CCH7245(148148/ha)	25.7	4.7	0.2	7.2	0.6	10.0	1812
V4-RCH2 *Bt* (18519/ha)	27.3	6.2	1.5	15.3	0.3	11.2	988
SE_D	1.9	0.5	0.2	2.5	0.1	0.5	115.4
CD (p=0.05)	NS	NS	0.5	6.1	0.2	NS	282
Nutrient levels (RDF)							
F1-75 (%)	25.7	53	0.5	7.7	0.4	10.1	1406
F2-100 (%)	25.4	5.0	0.6	8.7	0.5	10.2	1524
F3-125 (%)	25.1	5.0	0.4	8.5	0.5	10.0	1582
F4-150 (%)	25.0	5.1	0.6	8.6	0.5	10.3	1620
SE_D	1.1	0.3	0.2	1.0	0.1	0.3	84.2
CD(p=0.05)	NS	NS	NS	NS	NS	NS	NS

kg/ha at 120 DAS were recorded with genotypes of CCH 7245 followed by Anjali and C1412. The results interpreted that narrow row planted cotton produced significantly less number/plant busted bolls, leaf area and dry matter production but plant population kept was eight fold times higher than RCH 2 *Bt* under conventional spacing , which helped to produce more bolls/ unit area, leaf area index and dry matter production. Brodrick *et al.*, (2012) reported that biomass accumulation was higher in high density planting system (36 plants m"2) compared to the conventionally spaced cotton. The similar finding with high planting system with respect to production of significantly greater dry mass and leaf area index (LAI) was corroborated by Yao *et al.,* (2017). Numerical variation in growth characters observed at 45, 90,120 DAS under nutrient levels (75,100,125, And 150 per cent of RDF) were not significant statistically (Table 1, 2 and3).

Yield attributes : Conventionally planted RCH2 *Bt* (90x60 cm) had produced significantly higher no of bursted bolls (21.8), single plant yield (96.4 g) and boll weight (4.7 g) as compared to genotypes planted at high density (Table 4). As a woody perennial, cotton can take advantage of wide plant spacing, and produce higher per plant yield attributes if given sufficient time. .Similarly, wide row spacing had more bolls per plant over narrow spacing (Jahedi *et al.,* 2013). Single plant has greater opportunities to achieve maximum productivity when given ample room to grow. However, cotton farmers are more concerned with the community of plants in field and the combined productivity and profitability of the entire farm enterprise. Attempts to maximize the productivity of individual plants must be tempered by these larger considerations (Jahedi *et al.,* 2013).Amongst high density planting followed genotypes Anjali had been observed higher number of bursted bolls (5.4),

Table 2. Growth characters of genotypes as influenced by nutrient levels under high density planting system at 90 DAS (pooled data)

Genotypes	Plant height (cm)	Sym-podia	Mono-podia	LAI	Nodes	Bolls/ plant	Bolls (m^2)	Dry matter production (kg/ha)
V1-Anjali (148148/ha)	41.9	12.3	0.9	2.7	16.5	5.5	81.4	3588
V2-C1412(148148/ha)	46.6	12.6	0.4	3.3	17.1	4.0	59.2	3425
V3-CCH7245(148148/ha)	46.2	12.6	0.4	4.0	17.0	5.2	77.0	3605
V4-RCH2 *Bt* (18519/ha)	80.6	16.8	2.3	2.1	19.2	20.2	38.4	2174
SE d	2.8	0.8	0.3	0.3	0.7	0.7	3.1	279.0
CD (p=0.05)	6.8	2.0	0.6	0.8	NS	1.7	7.6	682
Nutrient Levels								
F1-(75%) RDF	53.1	12.3	1.0	3.0	17.3	8.2	68.1	3025
F2-(100%)RDF	55.8	13.0	1.0	2.8	17.3	8.6	71.4	3186
F3-(125%)RDF	54.1	13.2	1.0	3.1	17.7	8.9	73.9	3262
F4-(150%)RDF	52.3	12.8	1.0	3.2	17.4	9.2	76.4	3318
SE d	1.9	0.7	0.2	0.6	0.57	0.6	2.6	213
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

higher single plant yield (17.8 g) and boll weight (3.4 g) followed by CCH7245. The significantly less mean sympodial length (8.3 to 16.3 cm) had been measured with genotypes(V1,Anjali (8.3 cm) , V2,C1412,(16.3 cm) and V3,CCH7245, (9.1 cm) indicate that under high density planting system plant does not grow to form many long sympodial and monopodial branches peculiar to many situations by intra plant competition. Nutrient levels (75,100,125 and 150 % RDF) attempted in the trial, did not influence the yield attributes significantly.

Seed cotton yield : RCH 2 *Bt* produced the significantly least yield (1670 kg/ha) as compare to non *Bt* genotypes (V1,Anjali (2513kg/ha) , V2,C1412,(1922 kg/ha) and V3,CCH7245, (2349 kg/ha)) (Table 4) planted in HDPS. Adoption of conventional spacing (90 x 60 cm) to RCH 2 *Bt* hybrid invariably produced least LAI and lowest dry weight both at 90 and 120 DAS resulting in decline in seed cotton yield. When comparing of *Bt* with non *Bt* genotypes under conventional planting , *Bt* genotypes were performed better as reported by Sankaranarayan *et al.,* (2011) . Higher per plant biometric and yield attributes observed with RCH 2 *Bt* had not reflected in seed cotton yield because of agronomical advantage associated with high density planting system (45 x15 cm), which had resulted in 252 to 843 kg/ha higher seed cotton yield than RCH 2 *Bt*. High density planting had helped to produce higher biomass at all the growth stages because of optimal light penetration and uptake of major nutrients favored for increased photosynthetic efficiency and seed cotton yield. High density system had been shown to increase yields as compared with cotton grown in wider row spacing (Jahedi *et al.,* 2013).Under high density system, bolls/plant may be decreased, but yield is

Table 3. Growth characters of genotypes as influenced by nutrient levels under high density planting system at 120 DAS (pooled data)

Genotypes	Plant height (cm)	Sym-podia	Mono-podia	LAI	Nodes	Bolls/ plant	Bolls (m2)	Dry matter production (kg/ha)
V1-Anjali (148148/ha)	57.3	12.5	0.6	2.1	18.2	6.7	99.2	4857
V2-C1412(148148/ha)	63.6	13.1	0.3	2.5	19.2	5.6	82.9	3890
V3-CCH7245(148148/ha)	60.9	13.2	0.3	3.1	19.1	6.3	93.2	5231
V4-RCH2 *Bt* (18519/ha)	83.4	19.4	2.4	1.6	20.0	29.3	55.7	2657
SE d	3.5	0.7	0.1	0.6	1.3	0.3	6.0	446
CD (p=0.05)	8.6	1.8	0.3	1.6	NS	0.6	14.8	1092
Nutrient Levels								
F1-(75%) RDF	64.2	14.2	0.8	2.2	18.8	11.20	93.0	3852
F2-(100%) RDF	66.4	13.8	1.0	2.4	19.3	12.00	99.6	3928
F3-(125%) RDF	69.2	14.1	0.9	2.3	19.3	12.40	102.9	4362
F4-(150%) RDF	65.4	16.1	1.0	2.4	19.0	12.30	102.1	4494
SE d	2.8	0.6	0.2	0.5	1.0	0.2	4.2	381
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

maintained through high plant numbers (Yao *et al.,* 2017). Preliminary studies conducted at Central Institute for Cotton Research, RegionalStation, Coimbatore on high density planting of straight variety (Surabhi) found that planting at 90 x 10, 60 x 15 and 75 x 12 cm were on par but significantly higher than 75 x 30 cm planting. In 2009-2010, CCH 510-4 registered 2635 kg /ha under 90 x 10 cm spacing as compared to 1511 kg/ha with 90 x 45 cm spacing. The similar results were observed with LRA 5166 (34.5 % higher yield) and RCH 2 *Bt* (19 % higher yield)

Enhanced application of nutrient levels did not significantly influence seed cotton yield because fact that increased nutrientlevel did not favored for enhancing crop growth characters observed at 45, 90 and 120 DAS; which in turn produced statistically similar seed cotton yield. The Seed cotton yields were similar with 56, 112, and 168 kg N/ha under high density planting system (William *et al.,* 2010).

Quality parameters : Fibre quality parameters are by and large heritage (Venugopalan *et al.,* 2009). Quality parameters analysis found that significant variation is noticed amongst genotypes. The significantly highest 2.5 per cent span length (30.6 mm) fibre strength (21.6 g/tex),fibre quality index (344), estimated count(51),count strength product (2198) were recorded with RCH 2 *Bt* (Table 5). Amongst high density planting genotypes Anjali registered the significantly highest 2.5 per cent span length (27.4 mm), optimum micronaire (3.1 µ/inch), fibre strength (21.2 g/tex),fibre quality index(299), estimated count (43) and count strength product(2120).None of the quality parameters significantly influenced by nutrient levels (75,100,125 and 150 % of recommended nutrient levels). Nour Ali (2015) observed that N effects on fibre quality parameters were small and would not affect value or utilization. Jahedi *et al.*,(2013) reported that fiber quality parameters were not significantly affected by

Table 4. Yield attributes and seed cotton yield (kg/ha) as influenced by high density planting system (pooled data)

Genotypes	Yield (kg/ha)	Boll weight (g)	Bursted bolls/ plant	Single plant yield (g)	Harvest index	Sympodial length (cm)
V1-Anjali (148148/ha)	2513	3.4	5.4	17.8	0.49	8.3
V2-C1412(148148/ha)	1922	3.0	4.6	14.0	0.43	16.3
V3-CCH7245(148148/ha)	2349	3.3	5.1	16.9	0.43	9.1
V4-RCH2 *Bt* (18519/ha)	1670	4.7	21.8	96.4	0.51	30.2
SE d	128	0.12	0.25	1.3		1.3
CD (p=0.05)	313	0.25	0.6	3.1		3.1
Nutrient Levels						
F1-(75%) RDF	2017	3.5	8.8	35.6	0.46	15.2
F2-(100%) RDF	2090	3.5	9.2	35.9	0.47	16.2
F3-(125%) RDF	2169	3.7	9.3	36.2	0.47	15.8
F4-(150%) RDF	2177	3.7	9.6	37.4	0.44	16.8
SE d	69	0.12	0.21	1.2		1.1
CD (p=0.05)	NS	NS	NS	NS		NS

intra row spacing.

Economics : Prevailing market price of different agro inputs, price of *kapas* as per the market value of relevant count were considered while calculating economics. The significantly highest cost of cultivation (40, 102/ha), gross return (1, 04, 780/ha), net return (60, 231/ha), benefit cost ratio (2.61) were observed with cultivation of Anjali under high density planting system (Table 6). The economic assessment found that high density planting of Anjali had been arrived with the 33.0 and 25.9 per cent of higher gross return and net return respectively in comparison to RCH 2 *Bt*. The compactness, high yielding potential and moderate quality parameters linked with Anjali could helped to register more seed cotton yield under high density system and thereby resulted in higher economic return . Increase of plant density with decreasing cotton row spacing has been suggested as an alternative strategy to optimize cotton profit (Yao *et al.,* 2017).Cost of cultivation and economic returns had not been significantly influenced by nutrient levels. However application of 125 per cent nutrient level had been calculated the numerically highest net return (53,323/ha).The economics of nutrient use efficiency calculated to know the kilogram of seed cotton produced by/rupee investment on nutrients established that cultivation of Anjali under high density planting system registered the significantly highest one (0.9 kg/ ₹) and the least one (0.4 kg/ ₹) with RCH 2 *Bt*. Amongst nutrient levels, application with 75 per cent of nutrient levels registered the highest economic nutrient efficiency (0.9 kg/ ₹).

Table 5. Quality parameters as influenced by genotypes and nutrient levels under high density planting system (pooled data)

Genotypes	2.5 per cent span length (mm)	Uniformity ratio (%)	Micronaire	Strength (g/tex)	FQI	Count	CSP
V1-Anjali (148148/ha)	27.4	49.2	3.7	21.2	302	43	2125
V2-C1412(148148/ha)	27.0	47.9	4.3	21.0	273	38	2076
V3-CCH7245(148148/ha)	26.5	48.2	4.6	20.6	255	34	2043
V4-RCH2 *Bt* (18519/ha)	30.6	47.2	3.7	21.6	344	51	2198
SE d	0.4	0.5	0.2	0.3	9	1	78
CD (p=0.05)	1.0	NS	0.5	0.7	22	3	190
Nutrient Levels							
F1-(75%) RDF	27.9	48.1	4.0	21.6	301	43	2124
F2-(100%) RDF	28.3	48.2	4.1	20.8	291	41	2106
F3-(125%) RDF	27.2	48.4	4.0	20.9	284	40	2095
F4-(150%) RDF	28.1	47.9	4.2	21.2	291	41	2106
SE d	0.3	0.3	0.1	0.2	6.0	0.9	60.2
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

Input use efficiency : Light interception recorded at 90 DAS; found that the genotypes planted at high density registered significantly higher values (50.0 to 62.5 %). Amongst genotypes CCH7245, registered the significantly highest one (62.5%). The early canopy closure in high density system leads to a better light interception (Yao *et al.,* 2017).The conventionally planted RCH2 *Bt* registered lowest light interception (26.1%).The significantly lowest weed dry matter production (699 kg at 30 DAS and 391 kg at 60 DAS) and highest weed smothering efficiency (34.19% at 30 DAS and 47.39% at 60 DAS) were observed with CCH 7245.Which was followed by Anjali recorded 867 and 495 kg of weed DMP at 30 and 60 DAS, respectively and weed smothering efficiency of 18.41 and 33.48 per cent, respectively at 30 and 60 DAS(Table 8). High density production system enhance more rapid canopy closure (Yao *et al.,* 2017) that in turn reduces the weed competition (Madavi *et al.,* 2017) by higher weed smothering efficiency and produced less weed dry matter.

High density planting of Anjali (45x15 cm) had been calculated the highest of 64.4 kg/ha cm and 26.8 Rs/m^3 water use efficiency and water productivity respectively (Table 8). The performance of Anjali was closely followed by CCH7245 (WUE 60.2 kg ha-cm and water productivity of 24.3 /m^3).Venugopalan *et al.,* (2013) found greater water use efficiency for high density planting system under subsurface drip irrigation. The relative production and economic efficiency were arrived on the basis of the performance of RCH2 *Bt*, revealed that Anjali planted at 45x15 cm had 50.5 and 25.9 per cent higher, respectively. The improvement of 7.7 and 7.4 per cent of water use efficiencyand water productivity were observed, respectively by increasing RDF from 75 to 150 per cent. The relative production and economic efficiency were increased, respectively 4.16 and 4.60 per cent by application of 150 per cent of RDF from recommended level.

Nutrient uptake : Nutrient uptake of cotton was significantly influenced at harvest by genotypes and nutrient levels. The highest nutrient uptake of nitrogen (126.9 kg/ha) and potassium (97.1 kg/ha) were estimated with

Table 6. Economics as influenced by genotypes and nutrient levels under high density planting system (pooled data)

Genotypes	Cost of cultivation(‘/ha)	Gross return (/ha)	Net return(‘/ha)	B/C ratio	ENUE (Kg/ ‘)
V1-Anjali (148148/ha)	40102	104780	60231	2.61	0.9
V2-C1412(148148/ha)	35372	75269	45632	2.11	0.7
V3-CCH7245(148148/ha)	38792	94792	56106	2.43	0.8
V4-RCH2 *Bt* (18519/ha)	33363	78782	47848	2.34	0.4
SE d	1425	5248	3935	0.06	
CD (p=0.05)	3486	12842	9628	0.14	
Nutrient Levels					
F1-(75%) RDF	36138	84518	48380	2.32	0.9
F2-(100%) RDF	36720	87693	50973	2.36	0.7
F3-(125%) RDF	37353	90675	53323	2.40	0.6
F4-(150%) RDF	37417	90736	53319	2.41	0.5
SE d	1021	3812	2986	0.04	
CD (p=0.05)	NS	NS	NS	NS	

CCH7245 planted at high density planting (1, 48,000/ha), the result was *on par* with Anjali and C1412 (Table 7). Owing to higher N and P uptake, higher dry matter production was registered with these genotypes and uptake is a positive function of dry matter yield. The boosted dry matter production enabled the increased nutrient uptake by the plants (Makhdum *et al.*,

Table 7. Nutrient uptake and available nutrient status as influenced by genotypes and nutrient levels under high density planting system (pooled data)

Genotypes	Nutrient uptake (kg/ha)			Available nutrient status (kg/ha)		
	N	P	K	N	P_2O_5	K_2O
V1-Anjali (148148/ha)	120.7	19.0	89.1	210.6	13.2	654.6
V2-C1412(148148/ha)	119.9	21.3	93.4	218.6	12.8	712.8
V3-CCH7245(148148/ha)	126.9	20.0	97.1	208.3	11.8	648.6
V4-RCH2 *Bt* (18519/ha)	87.4	15.5	65.7	225.8	14.1	717.5
SE d	6.8	2.3	4.8	7.2	1.4	28.2
CD (p=0.05)	16.7	5.6	11.8	17.6	NS	NS
Nutrient levels						
F1-(75%) RDF	104.6	16.8	82.6	205.8	12.9	682.6
F2-(100%) RDF	114.3	18.6	86.7	215.2	11.6	710.0
F3-(125%) RDF	116.2	19.9	86.8	220.3	12.2	624.0
F4-(150%) RDF	119.7	20.5	89.2	222	15.2	716.9
SE d	4.8	1.6	3.8	5.9	1.2	21.6
CD (p=0.05)	9.9	3.3	7.8	12.2	2.5	NS

Table 8. Weed DMP, weed smothering efficiency, light interception water productivity and Nutrient uptake (kg/ha) and available nutrient status (kg/ha) as influenced by genotypes and nutrient levels under high density planting system (pooled data)

Genotypes	Weed DMP at 30 DAS (kg/ha)	Weed DMP at 60 DAS (kg/ha)	WSE at 30 DAS	WSE at 60 DAS	WUE (kg/ha -cm)	Light interce-ptionat 90 DAS (%)	Water produ-ctivity (Rs/M^3)	RPE (%)	REE (%)
V1-Anjali (148148/ha)	867	495	18.41	33.48	64.4	58.3	26.8	50.5	25.9
V2-C1412(148148/ha)	940	571	11.50	23.32	49.2	50.0	19.3	15.1	-4.6
V3-CCH7245(148148/ha)	699	391	34.19	47.39	60.2	62.5	24.3	40.7	17.3
V4-RCH2 *Bt* (18519/ha)	1062	744	-	-	42.8	26.1	20.2	0.0	0.0
SE d	80	44							
CD (p=0.05)	194	107							
Nutrient Levels									
F1-(75%) RDF	573	458			51.7	46.6	21.6	-3.49	-5.1
F2-(100%) RDF	699	519			53.5	50.7	22.5	0.0	0.0
F3-(125%) RDF	832	583			55.5	47.5	23.2	3.78	4.61
F4-(150%) RDF	810	640			55.7	52.1	23.2	4.16	4.60
SE d	93	53							
CD (p=0.05)	192	NS							

2007). Application of 150 per cent recommended dose of nutrients to genotypes had reached the significantly the highest nitrogen uptake (119.7 kg/ha), phosphorus (20.5 kg/ha), and potassium (89.2 kg/ha) uptake at harvest stage. This might be attributed to the fact that increased concentration of applied nutrients accel-erates the plants to take extra nutrients leading to higher DMP which in turn augments more nutrient uptake. This finding was in accordance with the earlier findings made by Makhdum *et al.*, (2007).

Post harvest soil fertility status : The status of available nutrients in the high density planting system is of major practical importance to promote the system in large scale. Soil available phosphorus and potassium had not been influenced significantly by the genotypes even though uptake was significant. This may be due to equilibrium between labile and non-labilepool ofnutrients operated and maintained the available phosphorus and potassium status in soil.However, enhanced application of nutrient level, had improved the available nutrient status of soil. The significantly highest nitrogen (220.3 kg/ha) and phosphorus (15.2 kg/ha) availability estimated with the application of 150 per cent of nutrient to genotypes (Table 7). Application of higher level of nutrients considerably built up the nutrient status of the soil. This might be due to mineralization of organically bound nutrients and the exchange reactions contributing towards better availability of nutrient elements present in the soil(Jacoby *et al.,* 2017). In the present study, the soil available potassium was not found to be altered advantageously by any of the treatments.

Adoption of *Bt* cotton technology reached almost saturation point and there is no further jump of productivity is expected by *Bt* cotton. Many countries likeBrazil, China, Australia), Spain,Uzbekistan,Argentina and Greece adopted high density planting system as tool to achieve higher productivity. Identification of genotypes and their response to nutrient levels under HDPS were investigated. The results interpreted that under high density planting system, plant does not grow to form many long sympodial and monopodial branches peculiar to many situations, high density planting of (45 x 15 cm, 1,48,148 plant/ha) non *Bt* genotypes (Anjali, CCH 7245 and C1412) had resulted in in 252 to 843 kg/ha higher seed cotton yield edge over to RCH 2 *Bt*(planted at 90 x 60 cm); in contrast to 20-25 per cent extra yield in *Bt* hybrids, reported in many situations over non *Bt* under conventional planting with normal density . The economic assessment found that high density planting of Anjali had arrived with the 33.0 and 25.9 per cent of higher gross return and net return respectively in comparison to RCH 2 *Bt*. Application of 125 per cent nutrient level had been calculated the highest net return (53,323/ ha).The further study with respect to improvement of suitable genotypes by transgenically, canopy management, mechanical planting, post emergence weed control and defoliation techniquescould make high density planting system is one of the futuristic technology and may play a major role in enhancing cotton production.

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